III.E.4 Hot Anode Recirculation Blower (HARB) for SOFC Systems

Objectives

- Develop configuration that can pump anode gas at 850°C.
- Develop thermal choke design and component test at full temperature (850°C).
- Verify bearing/seal selection and design.
- Integrate and evaluate controller/motor.
- Develop low-cost integrated assembly to provide required performance and offer low cost in high volume.

Accomplishments

- Completed bearing selection and design process; selected grease-for-life bearing with greater than 40,000 hours of life.
- Identified candidate pump head materials to ensure 40,000 hours of reliable high-temperature blower operation.
- Performed detailed thermal/structural analysis of the HARB prototype blower to optimize design configuration for proper thermal response and structural robustness.
- Completed detailed cost analysis of the prototype blower for DOE and SECA review.
- Manufactured test rig hardware to verify thermal choke effectiveness.
- Demonstrated the successful performance of the thermal choke through laboratory experimentation. Tests were completed to nearly 600°C.

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Introduction

This effort involves the development of a robust, low-cost, high-temperature anode recirculation blower (HARB) for use with solid oxide fuel cell (SOFC) systems (see Figure 1). SOFC system designers believe considerable improvements are achievable in water management, fuel utilization, stack operating efficiency, or system controllability if an anode recirculation pump is employed. The opportunity here is to develop a low-cost pump that can provide this function.

The challenge is to develop a pump that is durable and can survive in a very harsh environment. Unlike proton exchange membrane fuel cell (PEMFC) systems, SOFC systems operate at very high temperatures (~850°C). Depending on system architecture, the proposed pump may very well be exposed to these extreme conditions. Yet, the electric motor, controller, and bearings in the system must be kept at much cooler temperatures than the process flow. Therefore, the focus of this project is to develop an innovative approach to pump this hot process flow while providing cool temperatures for the sensitive pump components. Additionally, innovation is required to provide this capability and maintain low costs in high-volume production.

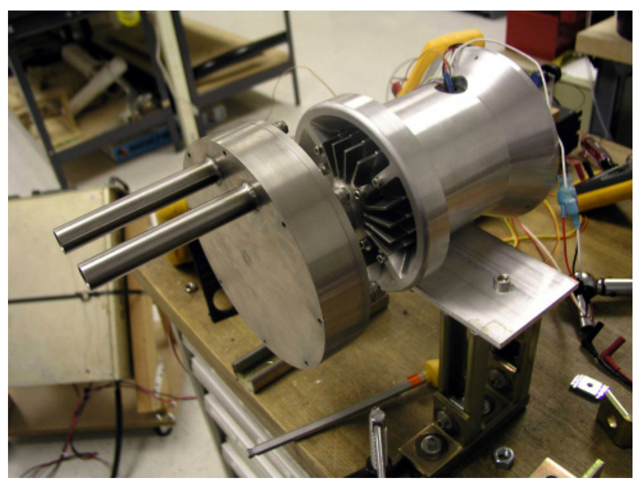

FIGURE 1. Phase I HARB Prototype Blower

Approach

The approach used to develop this pump emphasizes design iterations with a reduction to working prototypes in rapid succession. In Phase I, the major pump configuration and material selection were achieved with the aid of finite element modeling (FEM). FEM was done for all critical components to understand their temperature and stress situation. Many computer iterations were done. In particular, the thermal choke approach was confirmed and refined analytically.

After material selection and pump configuration were completed, CAD modeling and detailed drawings were done. The resulting design was procured and tested to verify performance and temperature levels. The testing confirmed the analysis and showed excellent correlation with prediction (see results section).

Results

The most important result from recent effort is the temperature data that was obtained from testing the prototype blower. The temperature data is shown in Figure 2 and is compared to an analytical prediction. This test shows surface temperatures on the outside of the thermal choke when the unit was run with ~600°C inlet temperature gas flow temperatures. The test rig that was used to create this data is shown in Figure 3.

A full view of the temperatures inside the machine, while operating at 850°C, is shown in the cross-sectional view of Figure 4.

Additionally, a cost study was completed for high-volume production of the blower shown in Figure 1. We found that the costs were too high, even in high volume, because of the size and materials used in the prototype. Therefore, based on the Phase I test results, a Phase II blower has been designed which meets long-term cost objectives. This is the most important result of our efforts to date, and the proposed design is shown in Figure 5.

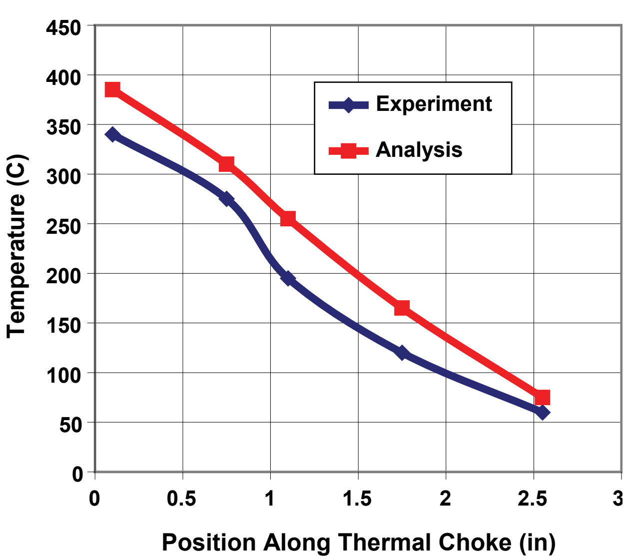

FIGURE 2. Thermal Choke Temperature Distribution (comparison between measured and analytical)

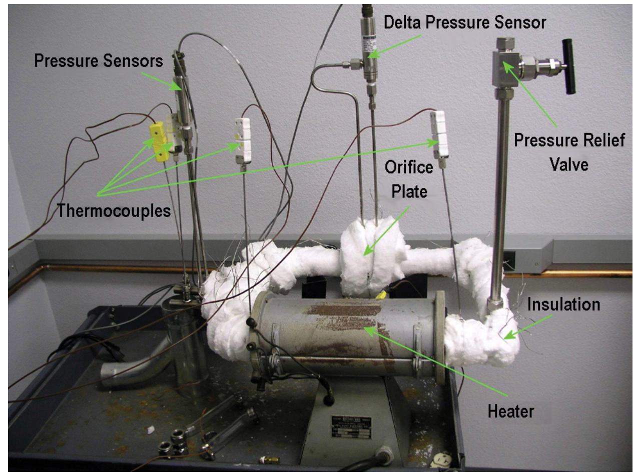

FIGURE 3. Phase I Laboratory Test Rig

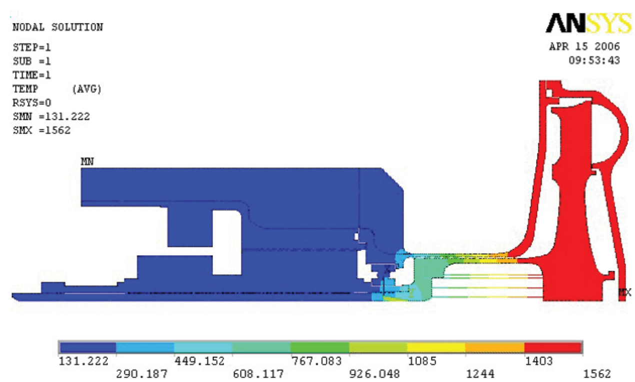

FIGURE 4. Analytical Temperature (F) Predictions for the HARB Blower

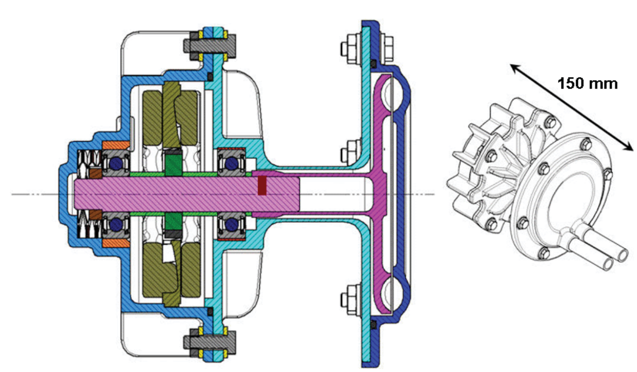

FIGURE 5. Cross-Section and Isometric View of Reduced-Cost Phase II Blower

Conclusions and Future Directions

Based on the work completed to date, a low-cost blower has been designed which will be undergoing development during Phase II. The major objectives for this effort are shown in Table 1.

TABLE 1. Phase II Primary Technical Objectives

OBJECTIVE		DISCUSSION
1	Complete details of reduced-cost design	Figure 5 presents a look at the cost-reduced configuration. However, it's necessary to finish this work by completing analyses and detailed drawings.
2	Characterize 850°C operation	The Phase I effort verified the thermal management design at part temperature (~600°C). In Phase II, hardware will be procured and a new blower constructed based on the Phase II reduced-cost concept. It will be tested at full temperature under a wide variety of conditions.
3	Demonstrate forward bearing life	In Phase I the forward bearing configuration was designed to survive at high temperatures (150°C). In Phase II several bearing tests will be conducted to verify this life and adjust the bearing approach accordingly.
4	Develop low-cost motor and controller	PADT has designed motors and controllers in the past. This application de-emphasizes performance in exchange for cost. Controller may be available off-the-shelf, or a prior PADT design will be modified.
5	Develop and integrate novel pump head aerodynamics	PADT is proposing a modified regenerative pump head which allows for a *much reduced impeller cost*. This is accomplished by using a technology that develops high pressure with a small wheel with relatively low tip speed.
6	Integrate improvements	Now we can integrate the low-cost motor design, improved pump head, best bearings tested to date, the sensorless controller, cast components, and any other lessons learned from the characterization and early endurance testing of objective 2, into the HARB design.
7	Validate design	Procure hardware and build three (3) HARB Phase II blowers. Conduct a bank of validation tests. A final low-cost version of the pump will be tested on a 5,000 hour endurance test at full power and high temperature. This will flush out any design flaws or issues and prepare us for low-volume production for SOFC demonstration projects.